Remarks

Reconsideration of this Application is respectfully requested.

Upon entry of the foregoing amendment, claims 1-14 are pending in the application, with claims 1 and 8 being the independent claims.

Based on the following remarks, Applicants respectfully request that the Examiner reconsider all outstanding objections and rejections and that they be withdrawn.

Description of the Invention

The present invention relates to integrated circuits. More specifically, the present invention relates to systems and methods for providing a one-time programmable memory element that is capable of being manufactured using 0.13μm or below CMOS technology. The present invention comprises a capacitor or a transistor configured as a capacitor that has a thin oxide layer. The thin oxide layer is capable of passing direct gate tunneling current. Furthermore, the present invention comprises a switch, coupled to the capacitor, having a higher voltage tolerance than the capacitor. The capacitor is one-time programmable as an anti-fuse. Whenever a specified *low* voltage is applied via the switch to the oxide layer, the oxide layer is ruptured forming a conductive path having a low resistance of approximately hundreds of Ohms or less. The present invention allows for a

controlled rupture of the oxide layer through gate tunneling current. Different embodiments of the present invention include oxide layers of 20Å thick.

Objection to the Specification

In the Office Action dated March 18, 2002, the Examiner objected to specification on Page 6, Line 1 and Page 7, Line 1 requiring appropriate corrections.

It is respectfully submitted that the Applicants have complied with Examiner's requirements by entering the above Amendments to the Specification. The Applicants respectfully request that these objections be reconsidered and withdrawn.

Rejections under 35 U.S.C. § 102

In the Office Action dated March 8, 2002, the Examiner rejected claims 1, 3-8, and 10-14 under 35 U.S.C. 102(e) as being anticipated by U.S. Patent No. 6,096,610 to Alavi *et al.* The Examiner stated that Alavi *et al.* teaches a semiconductor device having respective elements of the present invention. This rejection is respectfully traversed.

It is respectfully submitted that Alavi *et al.* does not anticipate the present invention. Alavi *et al.* does not disclose, teach or suggest the present invention's *thin* oxide layer. As claimed, the claimed oxide layer passes a direct tunneling current. Thick oxide layers are <u>not</u> capable of passing direct tunneling current. Alavi *et al.* does not disclose, teach or suggest anti-fuse devices comprising thin oxide layers as presently claimed.

According to Applicants' invention, the application of a *low* programming voltage to anti-fuse switch ruptures the oxide layer in a "controlled" manner (*see page 5, lines 9-14 and page 6, lines 3-13 of Applicants' specification and claims 1 and 8*). When the thin oxide layer is ruptured, a conductive path of only hundreds of Ohms or less is formed. An advantage of the present invention is that programming voltage is *low*, thus, eliminating the need for a charge pump circuit and yielding a "controlled" rupture. The gate tunneling current in the present invention generates sufficient localized oxide trap charges, which cause gate oxide breakdown. Therefore, the present invention, unlike Alavi *et al.*, is capable of maintaining a well "controlled" programmed resistance with a small variation. The "controlled" rupture results in an anti-fuse capacitor (or transistor configured as a capacitor) having virtually 100% reliability, which permits use of the present invention in the area of post package programming to install security codes, for example.

Alavi *et al.* describes an anti-fuse device having a thick oxide layer that requires application of high programming voltage and current to breakdown the oxide layer. A pinhole is formed in the oxide layer of the anti-fuse device when high voltage is applied. This creates a conductive path and causes a breakdown of the anti-fuse device. Before breakdown, the anti-fuse forms a high resistance electrical connection. After breakdown, the anti-fuse forms a low resistance electrical connection. (See Alavi *et al.*, Col. 3, Line 65 to Col. 4, Line 14). Alavi *et al.* does not describe the present invention's thin oxide layer capable of passing direct gate tunneling current. By applying direct gate tunneling current in the present invention, a "controlled" breakdown of the oxide layer occurs resulting in a predictable low impedance of the ruptured anti-fuse.

The present invention's mechanism of breakdown of the oxide layer is different from the Alavi *et al.* patent's mechanism because of the marked differences between thin and thick oxide layers. Alavi *et al.*'s thick oxide layer is not capable of passing the direct gate tunneling current to cause a breakdown of the anti-fuse device. An application of high programming voltage to the oxide layer creates a conductive path having an unpredictable impedance. The final resistance of the conductive path in Alavi *et al.* can vary up to 1000's of Ohms. This is unlike the present invention, where by using a thin oxide layer, which undergoes different characteristic breakdown mechanism, the present invention yields an anti-fuse having final predictable resistance that has an order of magnitude lower variation. (*See page 5, lines 18-20 and page 8, lines 24-28 of Applicants' specification*).

Further differences of breakdown patterns of thin and thick oxide layers are described with respect to an oxide's Q_{BD}. Q_{BD} is the charge density flowing through the oxide layer necessary to break it down. *See FIG. 6.40, page 397, K. Schroder, "Semiconductor Material and Device Characterization", John Wiley and Sons, 2nd Ed., 1988* (copy enclosed). As shown in FIG. 6.40 of Schroder, the thick oxide layer's Q_{BD} behaves differently than thin oxide layer's Q_{BD}. The present invention utilizes a thin oxide layer having a high Q_{BD}. By contrast, Alavi *et al.* describes a thick oxide layer having a varying Q_{BD}. The varying Q_{BD} is a result of various defects present in the thicker oxide layers.

By applying (for example) a breakdown voltage of more than 4V (or more than 20MV/cm) to the thin oxide layer in the present invention, the oxide is in the intrinsic oxide breakdown mode (*See FIG. E6.5(a), page 391 of K. Schroder, supra*). The

intrinsic mode is free from defects that negatively affect Q_{BD}. Thicker oxide layers cannot be in the intrinsic oxide breakdown mode because Q_{BD} is varying and is not high enough.

Therefore, thicker oxide layers, as in Alavi *et al.*, having a varying Q_{BD} require a high programming voltage to breakdown, which results in an unpredictable impedance of the formed conductive path. This is different from the present invention, where a thin oxide layer having a high Q_{BD} requires application of direct gate tunneling current to break it down. The result is the low resistance path having predictable impedance.

Specifically, Alavi *et al.* describes an oxide layer of 3.5nm thick and therefore requiring a high programming voltage to breakdown the oxide layer (See Col. 4, Lines 4-14). Whereas, the present invention describes a thin oxide layer, which in one embodiment is 20Å thick *(See claims 2 and 9)*. The thickness of the oxide layer in the present invention is significantly smaller than the thickness of the oxide layer disclosed by Alavi *et al.* Furthermore, to apply high programming voltage, Alavi *et al.* requires a separate power supply current, or a charge pump circuit. Because a thin oxide layer is implemented in the present invention, a separate charge pump circuit is not required. Thus, Alavi *et al.* does not anticipate, nor render obvious Applicants' claimed invention, because it does not teach or suggest a thin oxide anti-fuse device.

Claims 3-6 and 10-13, which depend from claims 1 and 8, respectively, are not anticipated by the Alavi *et al.* for at least the reasons set forth above.

Applicants respectfully request that the Examiner reconsider and withdraw the rejection of claims 1, 3-8 and 10-14.

Rejections under 35 U.S.C. § 103

Claims 2 and 9 were rejected under 35 U.S.C. 103(a) as being unpatentable over U.S. Patent No. 6,096,610 to Alavi *et al.* The Examiner stated that the elements described in claims 2 and 9 would have been obvious to a person having ordinary skill in the art. This rejection is respectfully traversed for at least the reasons set forth above.

Based on the above arguments, it would not have been obvious to one having ordinary skill in the art at the time the invention was made to include a thin oxide layer of 20 Å thick in the Alavi *et al.* anti-fuse. Such thickness of the oxide layer is not achieved through methods described in Alavi *et al.* Nor is a charge pump appropriate for a thin oxide device. No suggestion is provided by Alavi *et al.* for eliminating the charge pump or using a thin oxide. Thus, it is respectfully submitted that recitation of In re Boesch, 617 F.2d 272, 205 USPQ 215 (CCPA 1980) is unfounded.

Applicants respectfully request that the Examiner reconsider and withdraw the rejection of claims 2 and 9.

Conclusion

All of the stated grounds of objection and rejection have been properly traversed, accommodated, or rendered moot. Applicants therefore respectfully request that the Examiner reconsider all presently outstanding objections and rejections and that they be

withdrawn. Applicants believe that a full and complete reply has been made to the outstanding Office Action and, as such, the present application is in condition for allowance. If the Examiner believes, for any reason, that personal communication will expedite prosecution of this application, the Examiner is invited to telephone the undersigned at the number provided.

Prompt and favorable consideration of this Amendment and Reply is respectfully requested.

Respectfully submitted,

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Version with markings to show changes made

In the Specification:

Substitute the paragraph beginning on page 1, line 25, with the following paragraph:

> The dielectric material separating the polysilicon gate from the channel region, henceforth referred to as the gate oxide, usually consists of the thermally grown silicon dioxide (SiO_2) material that leaks very little current through a mechanism called Fowler-Nordheim tunneling under voltage stress. When stressed beyond a critical electrical field (applied voltage divided by the thick[en]ness of the oxide), the transistor is destroyed by rupturing of the oxide.

Substitute the paragraph beginning on page 5, line 28, with the following paragraph:

> FIG. 1 illustrates a block diagram of a one-time programmable storage cell and ancillary circuitry, according to the present invention. The block diagram of FIG. 1 includes a storage cell 102, and a write circuit 10[3]4, a read circuit 106 and a current bias and voltage clamp circuit 108.

Substitute the paragraph beginning on page 6, line 25, with the following paragraph:

> Rload is coupled between the vload node and switches 212 and 214 via a connection labeled "n3v5out" (negative 3.5 volt out). Closing of write switches 206 and 214, while read switches 208, 210 and 212 remain open, permits sufficient current to flow through the vload node to rupture the anti-fuse. Once programmed in this manner, the anti-fuse can be read by read circuit 106. In this arrangement, write switch 206 must have a voltage tolerance higher than that of the an[it]ti-fuse. To achieve this higher [a]voltage tolerance, the switches, including write switch 206, are formed with thicker gate oxide layers (e.g., 50-70 μm).